

Data description

Dr.-Ing. Christian Willberg*

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1 Loads

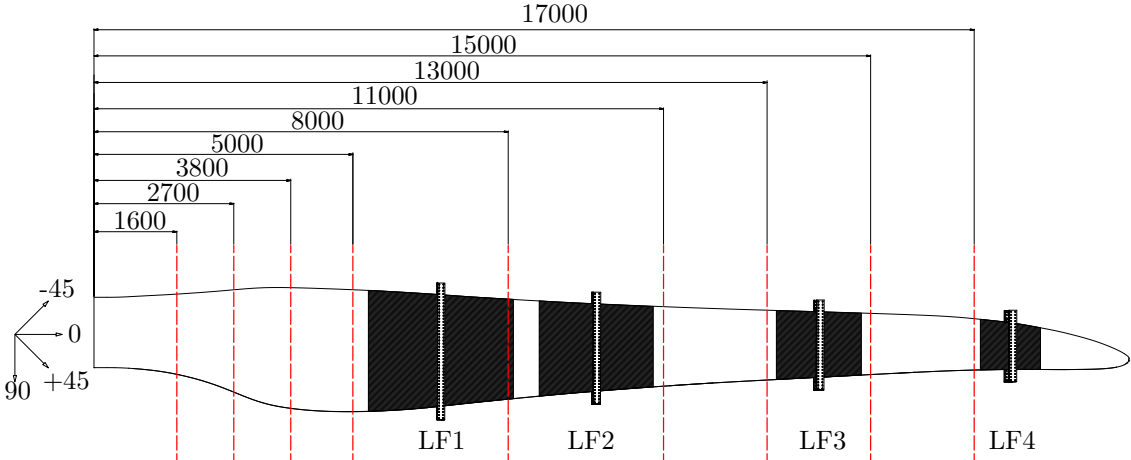


Figure 1: Positions of strain gauges and definition of the load frames (LF 1 - 4)

Load point	Radius [m]	Mxmax[kN]	Mxmin [kN]	Mymax [kN]	Mymin [kN]
1	6.7	10.1	0.0	0.0	0.0
2	9.7	0.0	6.5	21.8	14.9
3	14.0	0.0	11.3	18.8	19.8
4	17.7	12.6	6.3	24	15.9

Table 1: Applied loads for all the bending load cases applied in the shear center via load frames

*christian.willberg@dlr.de;ORCID: 0000-0003-2433-9183

- For the test LC1, due to a measurement mistake, the upper attachment was shifted 158 mm toward the leading edge.
- For the test LC1, the load frame 1 was dismantled, for the test LC2, the load frames 1 and 2 were dismantled and for the test LC3, the load frames 1, 2 and 3 were dismantled to reduce stiffening effects.

Scenario	Radius [m]	Load up [kN]	Load down [kN]
LC1	9.7	18.7	30.0
LC2	14.0	29.1	30
LC3	17.7	31.6	30.0

Table 2: Applied loads and load frame positions for all the torsion load cases (LC)

2 Load frame geometry

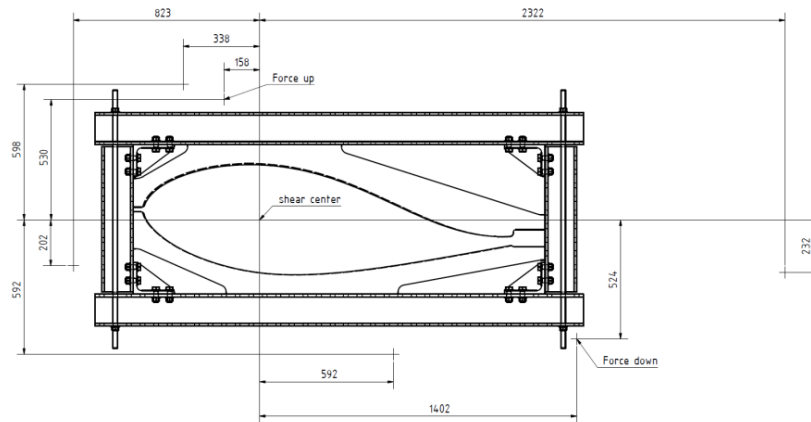


Figure 2: Torsion test LC1 load and optical measurement points

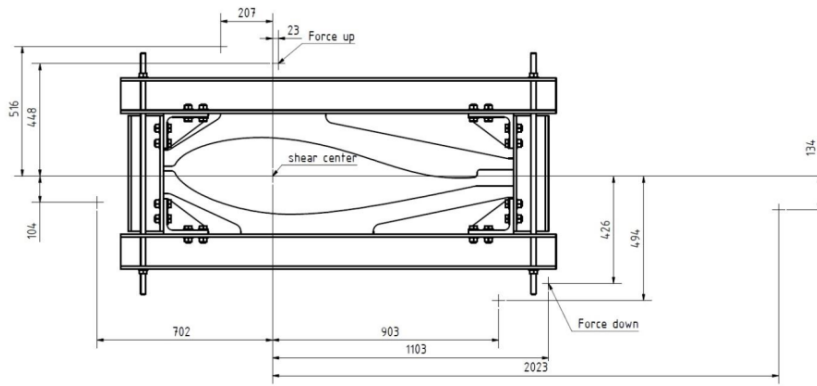


Figure 3: Torsion test LC2 load and optical measurement points

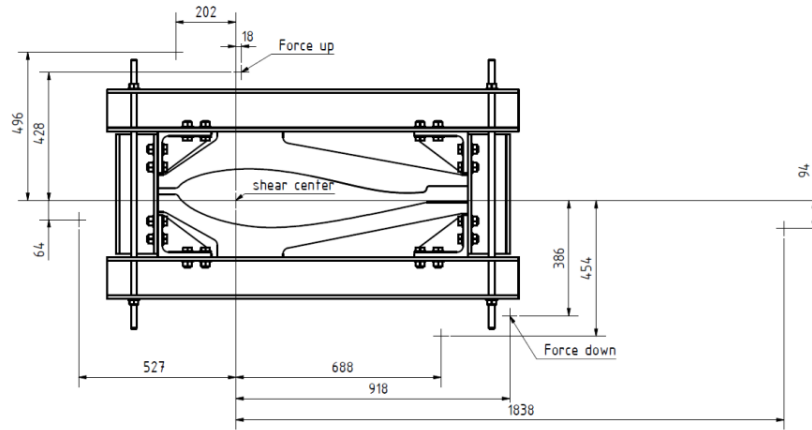


Figure 4: Torsion test LC3 load and optical measurement points

3 Material

Material	Abaqus	Ansys	Nastran
UD	MAT_UD	7	7
2AX45	MAT_2AX-45_45	22	22
2AX90	MAT_2AX-0_90	24	24
3AX	MAT_3AX	18	18
3AX manual layup	MAT_3AX_HANDLAMINAT	4	4
Balsa Baltek SB.100	MAT_BALSA_SB100	12	12
Foam Airex C70-55-20mm-spar	MAT_SCHAUMSTEGAIRES_C70-55	32	32
Foam Airex C70-55-20mm	SCHAUM_AIREX_C70-55-20MM	37	37
Foam Airex C70-55-15mm	SCHAUM_AIREX_C70-55-15MM	25	25
Foam Airex C70-55-10mm	SCHAUM_AIREX_C70-55-10MM	19	19
Foam Airex C70-55-5mm	SCHAUM_AIREX_C70-55-5MM	13	13
ADH/HARDENER	ADH/HARDENER	23	23

Table 3: Material number in the finite element models

Material	Orientation	E_1 [MPa]	E_2 [MPa]	G_{12} [MPa]	ν_{12} [-]	ρ [kg/m ³]	h [mm]
UD	0°	44151	14526	3699	0.3	1948	0.827
2AX45	±45°	11316	11316	11978	0.633	1875	0.625
	0.892						
2AX90	0°/90°	26430	27520	3464	0.124	1875	0.651
3AX	0°/ ± 45°	29873	13377	6918	0.466	1875	0.922
3AX manual layup	0°/ ± 45°	21888	9473	5126	0.46	1658	1.318
Balsa Baltek SB.100		35	35	105	0.3	291 ¹	19.05
Foam Airex C70-55-20mm-spar		55	55	22	0.3	180 ¹	20
Foam Airex C70-55-20mm		55	55	22	0.3	279 ¹	20
Foam Airex C70-55-15mm		55	55	22	0.3	314 ¹	15
Foam Airex C70-55-10mm		55	55	22	0.3	384 ¹	10
Foam Airex C70-55-5mm		55	55	22	0.3	596 ¹	5
ADH/HARDENER		4864	4864	1828	0.33	1160	-
Pseudo material		10	10	3.84	0.3	1.0E-5	0.1

Table 4: Material parameters based on [1]. 1-Values after matrix infusion

Name	Explanation	Abaqus	Ansys	Nastran
Pseudo Material	all elements between 0m-1m	MATPOS_0-1000MM	1	1
Pseudo Material	all elements between 6m-7m	MATPOS_6000-7000MM	2	3
Pseudo Material	all elements between 12m-13m	MATPOS_12000-13000MM	3	3
3AX manual layup	triaxial glas fiber manual layup	MAT_3AX_HANDLAMINAT	4	4
Pseudo Material	all elements between 15m-16m	MATPOS_15000-16000MM	5	5
Pseudo Material	all trailing edge elements	MATPOS_TE	6	6
UD	unidirectional glas fiber	MAT_UD	7	7
Pseudo Material	all elements between 18m-19m	MATPOS_18000-19000MM	8	8
Pseudo Material	all elements of the spar cap	MATPOS_SPARCAP	9	9
Pseudo Material	all elements between 14m-15m	MATPOS_14000-15000MM	10	10
Pseudo Material	all elements between 4m-5m	MATPOS_4000-5000MM	11	11
Balsa Baltek SB.100	Balsa wood material	MAT_BALSA_SB100	12	12
Foam Airex C70-55-5mm	Foam material	SCHAUM_AIREX_C70-55-5MM	13	13
Pseudo Material	all elements of the suction side	MATPOS_SS	14	14
Pseudo Material	all elements between 3m-4m	MATPOS_3000-4000MM	15	15
Pseudo Material	all elements between 11m-12m	MATPOS_11000-12000MM	16	16
Pseudo Material	all elements of the root	MATPOS_ROOT	17	17
3AX	all elements between 12m-13m	MAT_3AX	18	18
Foam Airex C70-55-10mm	Foam material	SCHAUM_AIREX_C70-55-10MM	19	19
Pseudo Material	all elements between 16m-17m	MATPOS_16000-17000MM	20	20
Pseudo Material	all elements between 2m-3m	MATPOS_2000-3000MM	21	21
3AX manual layup	all elements between 12m-13m	MAT_2AX-45_45	22	22
3AX manual layup	all elements between 12m-13m	ADH/HARDENER	23	23
3AX manual layup	all elements between 12m-13m	MAT_2AX-0.90	24	24
Foam Airex C70-55-15mm	Foam material	SCHAUM_AIREX_C70-55-15MM	25	25
Pseudo Material	all elements between 1m-2m	MATPOS_1000-2000MM	26	26
Pseudo Material	all elements between 9m-10m	MATPOS_9000-10000MM	27	27
Pseudo Material	all elements between 13m-14m	MATPOS_13000-14000MM	28	28
Foam Airex C70-55	Foam material (not used)	MAT_SCHAUMSTEGAIRES_C70-55	29	29
Balsa Baltek SB.150	Balsa wood material (not used)	SB150	30	30
Pseudo Material	all elements for the end of the spar to tip	MATPOS_REST	31	31
Foam Airex C70-55-20mm-spar	Foam material in the spar	SCHAUM_AIREX_C70-55-20MM_STEG	32	32
Pseudo Material	all elements between 17m-18m	MATPOS_17000-18000MM	33	33
Pseudo Material	all elements of the belts	MATPOS_BELT	34	34
Pseudo Material	all elements between 10m-11m	MATPOS_10000-11000MM	35	35
Pseudo Material	all elements of the pressure side	MATPOS_PS	36	35
Foam Airex C70-55-20mm	Foam material	SCHAUM_AIREX_C70-55-20MM	37	37

Table 5: List of materials.

4 Strain gauge list

Radial position [mm]	Strain Gauge	Component	element number
1600	001_Z01600_SS_LE.00	SS	LE
1600	002_Z01600_PS_LE.00	SS	LE
1600	003_Z01600_PS_SC.00	PS	B
1600	004_Z01600_PS_TE.00	PS	TE
1600	005_Z01600_SS_TE.00	SS	TE
1600	006_Z01600_SS_SC.00	SS	B
1600	007_Z01600_SW_TE.00	SW	TE
1600	008_Z01600_SW_TE.+45	SW	TE
1600	009_Z01600_SW_TE.-45	SW	TE
2700	010_Z02700_SS_LE.00	SS	LE
2700	011_Z02700_PS_LE.00	PS	LE
2700	012_Z02700_PS_SC.00	PS	B
2700	013_Z02700_PS_TE.00	PS	TE
2700	014_Z02700_SS_TE.00	SS	TE
2700	015_Z02700_SS_SC.00	SS	B
3800	016_Z03800_SS_LE.00	SS	TE
3800	017_Z03800_PS_LE.00	PS	TE
3800	018_Z03800_PS_SC.00	SS	B
3800	019_Z03800_PS_TE.00	PS	TE
3800	020_Z03800_SS_TE.00	SS	TE
3800	021_Z03800_SS_SC.00	SS	B
5000	022_Z05000_SS_LE.00	SS	LE
5000	023_Z05000_SS_LE.90	SS	LE
5000	024_Z05000_PS_LE.00	PS	LE
5000	025_Z05000_PS_LE.90	PS	LE
5000	026_Z05000_PS_LE.+45	PS	LE
5000	027_Z05000_PS_LE.-45	PS	LE
5000	028_Z05000_PS_LE_OPL1.00	PS	LE
5000	029_Z05000_PS_LE_OPL1.90	PS	LE
5000	030_Z05000_PS_LE_OPL2.00	PS	LE
5000	031_Z05000_PS_LE_OPL2.90	PS	LE
5000	032_Z05000_PS_LE_OPL3.00	PS	LE
5000	033_Z05000_PS_LE_OPL3.90	PS	LE
5000	034_Z05000_PS_SC.00	PS	B
5000	035_Z05000_PS_SC.90	PS	B
5000	036_Z05000_PS_SC.+45	PS	B
5000	037_Z05000_PS_SC.-45	PS	B
5000	038_Z05000_PS_TE_OPL4.00	PS	TE
5000	039_Z05000_PS_TE_OPL4.90	PS	TE
5000	040_Z05000_PS_TE_OPL3.00	PS	TE
5000	041_Z05000_PS_TE_OPL3.90	PS	TE

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Radial position [mm]	Strain Gauge	Component	element number
5000	042_Z05000_PS_TE_OPL2_00	PS	TE
5000	043_Z05000_PS_TE_OPL2_90	PS	TE
5000	044_Z05000_PS_TE_OPL1_00	PS	TE
5000	045_Z05000_PS_TE_OPL1_90	PS	TE
5000	046_Z05000_PS_TE_00	PS	TE
5000	047_Z05000_PS_TE_90	PS	TE
5000	048_Z05000_SS_TE_00	SS	TE
5000	049_Z05000_SS_TE_90	SS	TE
5000	050_Z05000_SS_TE_+45	SS	TE
5000	051_Z05000_SS_TE_-45	SS	TE
5000	052_Z05000_SS_TE_OPL1_00	SS	TE
5000	053_Z05000_SS_TE_OPL1_90	SS	TE
5000	054_Z05000_SS_TE_OPL2_00	SS	TE
5000	055_Z05000_SS_TE_OPL2_90	SS	TE
5000	056_Z05000_SS_TE_OPL3_00	SS	TE
5000	057_Z05000_SS_TE_OPL3_90	SS	TE
5000	058_Z05000_SS_TE_OPL4_00	SS	TE
5000	059_Z05000_SS_TE_OPL4_90	SS	TE
5000	060_Z05000_SS_SC_00	SS	B
5000	061_Z05000_SS_SC_90	SS	B
5000	062_Z05000_SS_SC_+45	SS	B
5000	063_Z05000_SS_SC_-45	SS	B
5000	064_Z05000_SS_LE_OPL3_00	SS	LE
5000	065_Z05000_SS_LE_OPL3_90	SS	LE
5000	066_Z05000_SS_LE_OPL2_00	SS	LE
5000	067_Z05000_SS_LE_OPL2_90	SS	LE
5000	068_Z05000_SS_LE_OPL1_00	SS	LE
5000	069_Z05000_SS_LE_OPL1_90	SS	LE
8000	070_Z08000_SS_LE_00	SS	LE
8000	071_Z08000_SS_LE_90	SS	LE
8000	072_Z08000_PS_LE_00	PS	LE
8000	073_Z08000_PS_LE_90	PS	LE
8000	074_Z08000_PS_LE_+45	PS	LE
8000	075_Z08000_PS_LE_-45	PS	LE
8000	076_Z08000_PS_LE_OPL1_00	PS	LE
8000	077_Z08000_PS_LE_OPL1_90	PS	LE
8000	078_Z08000_PS_LE_OPL2_00	PS	LE
8000	079_Z08000_PS_LE_OPL2_90	PS	LE
8000	080_Z08000_PS_SC_00	PS	B
8000	081_Z08000_PS_SC_90	PS	B
8000	082_Z08000_PS_SC_+45	PS	B
8000	083_Z08000_PS_SC_-45	PS	B
8000	084_Z08000_PS_TE_OPL4_00	PS	TE
8000	085_Z08000_PS_TE_OPL4_90	PS	TE

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Radial position [mm]	Strain Gauge	Component	element number
8000	086_Z08000_PS_TE_OPL3_00	PS	TE
8000	087_Z08000_PS_TE_OPL3_90	PS	TE
8000	088_Z08000_PS_TE_OPL2_00	PS	TE
8000	089_Z08000_PS_TE_OPL2_90	PS	TE
8000	090_Z08000_PS_TE_OPL1_00	PS	TE
8000	091_Z08000_PS_TE_OPL1_90	PS	TE
8000	092_Z08000_PS_TE__00	PS	TE
8000	093_Z08000_PS_TE__90	PS	TE
8000	094_Z08000_SS_TE__00	SS	TE
8000	095_Z08000_SS_TE__90	SS	TE
8000	096_Z08000_SS_TE__+45	SS	TE
8000	097_Z08000_SS_TE__ -45	SS	TE
8000	098_Z08000_SS_TE_OPL1_00	SS	TE
8000	099_Z08000_SS_TE_OPL1_90	SS	TE
8000	100_Z08000_SS_TE_OPL2_00	SS	TE
8000	101_Z08000_SS_TE_OPL2_90	SS	TE
8000	102_Z08000_SS_TE_OPL3_00	SS	TE
8000	103_Z08000_SS_TE_OPL3_90	SS	TE
8000	104_Z08000_SS_TE_OPL4_00	SS	TE
8000	105_Z08000_SS_TE_OPL4_90	SS	TE
8000	106_Z08000_SS_SC__00	SS	B
8000	107_Z08000_SS_SC__90	SS	B
8000	108_Z08000_SS_SC__+45	SS	B
8000	109_Z08000_SS_SC__ -45	SS	B
8000	110_Z08000_SS_LE_OPL2_00	SS	LE
8000	111_Z08000_SS_LE_OPL2_90	SS	LE
8000	112_Z08000_SS_LE_OPL1_00	SS	LE
8000	113_Z08000_SS_LE_OPL1_90	SS	LE
8000	114_Z08000_SW_TE_00	SW	TE
8000	115_Z08000_SW_TE_+45	SW	TE
8000	116_Z08000_SW_TE_-45	SW	TE
11000	117_Z11000_SS_LE_00	SS	LE
11000	118_Z11000_PS_LE_00	PS	LE
11000	119_Z11000_PS_SC_00	PS	B
11000	120_Z11000_PS_TE_00	PS	TE
11000	121_Z11000_SS_TE_00	SS	TE
11000	122_Z11000_SS_SC_00	SS	B
13000	123_Z13000_SS_LE_00	SS	LE
13000	124_Z13000_PS_LE_00	PS	LE
13000	125_Z13000_PS_SC_00	PS	B
13000	126_Z13000_PS_TE_00	PS	TE
13000	127_Z13000_SS_TE_00	SS	TE
13000	128_Z13000_SS_SC_00	SS	B
15000	129_Z15000_SS_LE_00	SS	LE

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Radial position [mm]	Strain Gauge	Component	element number
15000	130_Z15000_PS_TE.00	PS	TE
15000	131_Z15000_PS_LE.00	PS	LE
15000	132_Z15000_PS_LE.+45	PS	LE
15000	133_Z15000_PS_LE.-45	PS	LE
15000	134_Z15000_PS_SC.00	PS	TE
15000	135_Z15000_PS_SC.+45	PS	TE
15000	136_Z15000_PS_SC.-45	PS	TE
15000	137_Z15000_SS_TE.00	SS	TE
15000	138_Z15000_SS_TE.+45	SS	TE
15000	139_Z15000_SS_TE.-45	SS	TE
15000	140_Z15000_SS_SC.00	SS	B
15000	141_Z15000_SS_SC.+45	SS	B
15000	142_Z15000_SS_SC.-45	SS	B
15000	143_Z15000_SW_TE.00	SW	TE
15000	144_Z15000_SW_TE.+45	SW	TE
15000	145_Z15000_SW_TE.-45	SW	TE
17000	146_Z17000_SS_LE.00	SS	LE
17000	147_Z17000_PS_LE.00	PS	LE
17000	148_Z17000_PS_SC.00	PS	LE
17000	149_Z17000_PS_TE.00	PS	TE
17000	150_Z17000_SS_TE.00	SS	TE
17000	151_Z17000_SS_SC.00	SS	B

Table 6: List of strain gauges at components (PS - pressure side, SS - suction side, SW - shear web)and position (LE - leading edge, TE - trailing edge, B - belt).

ε_a	ε_b	ε_c	Shear sensor
008_Z01600_SW_TE_+45	007_Z01600_SW_TE_00	009_Z01600_SW_TE_-45	007_0 08_009_Z01600_SW_TE_00_+45_-45
115_Z08000_SW_TE_+45	114_Z08000_SW_TE_00	116_Z08000_SW_TE_-45	114_1 15_116_Z08000_SW_TE_00_+45_-45
141_Z15000_SS_SC_+45	140_Z15000_SS_SC_00	142_Z15000_SS_SC_-45	140_1 41_142_Z15000_SS_SC_00_+45_-45
144_Z15000_SW_TE_+45	143_Z15000_SW_TE_00	145_Z15000_SW_TE_-45	143_1 44_145_Z15000_SW_TE_00_+45_-45
135_Z15000_PS_SC_+45	134_Z15000_PS_SC_00	136_Z15000_PS_SC_-45	134_1 35_136_Z15000_PS_SC_00_+45_-45

Table 7: List of sensor combinations to extract the shear strain.

References

- [1] Wolfgang Heydlauff. Materialspezifikation der Faserverbundwerkstoffe für das Rotorblatt IWES20.0 - Testbench Version - Rev. 2.0. Technical report, Aero Dynamik Consult, 2018.